Chromospheric Evaporation in a recent joint IRIS/EIS flare observation

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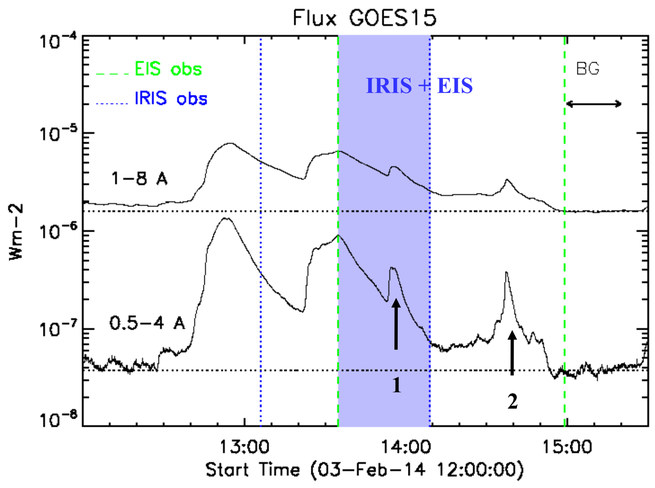
Abstract

Chromospheric evaporation during the impulsive phase of a flare is interpreted as the result of intense heating of the chromospheric plasma to flare temperatures with consequent expansion and filling of coronal loops. Spectral signatures of chromospheric evaporation are velocity blueshifts in high temperature emission, which were first observed in the X-ray wavelength range.

In this work we present a recent observation of a C6.5 class flare obtained with both the Interface Region Imaging Spectrometer (IRIS) and the EUV Imaging Spectrometer (EIS) in February 2014. We follow the details of the impulsive phase with IRIS and the gradual decay phase with EIS. Of particular interest is the Fe XXI emission line observed by IRIS, which is formed at 10 MK. It represents the highest temperature emission line observed in the IRIS wavelength range, and its intensity is typically enhanced during solar flares. Thanks to the high spatial and spectral resolution of the IRIS spectrograph, we are able to observe blueshifts at the flare ribbons during the impulsive phase. The blueshifts and the non-thermal width progressively decrease until the peak phase, where the profile is dominated by the rest wavelength emission. IRIS Slit-Jaw Images are used to precisely locate the flare kernels where the blueshifted emission originates. Hot (10 MK) Fe XXIII and Fe XXIV emission from the filled coronal loops is also observed by EIS during the decay phase.

IRIS/EIS Joint Observation 3 Feb 2014



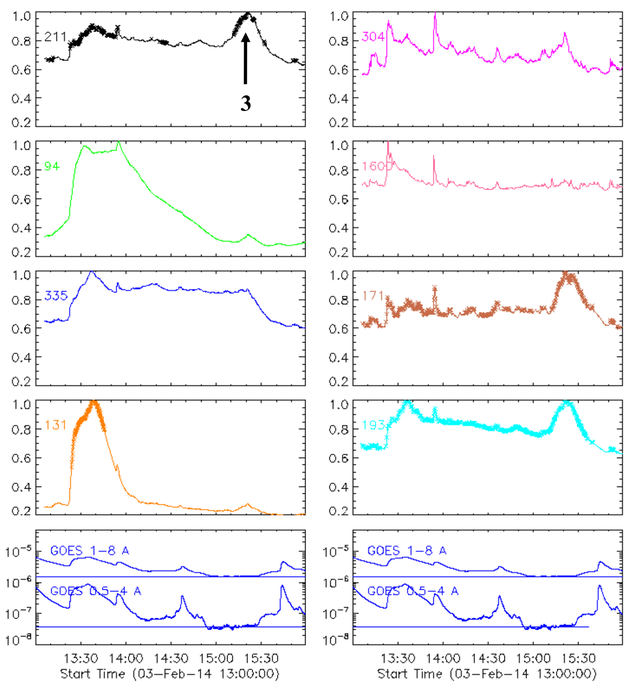
C6.5 class flare
Peak time 13:34 UT
IRIS observation
Exposures: 8x2.01"
Exposure Cad: 9.4s
Raster Cad: 75s, 50 rasters
EIS Observation
Steps:53x2"
Step Cad: 3 s
Raster Cad: 250s, 14 rasters

The GOES light curves show post-flare peaks around 13:54 UT and 14:36 UT (indicated as 1 and 2 in the figure). They are also present in the AIA light curves obtained over the flare region.

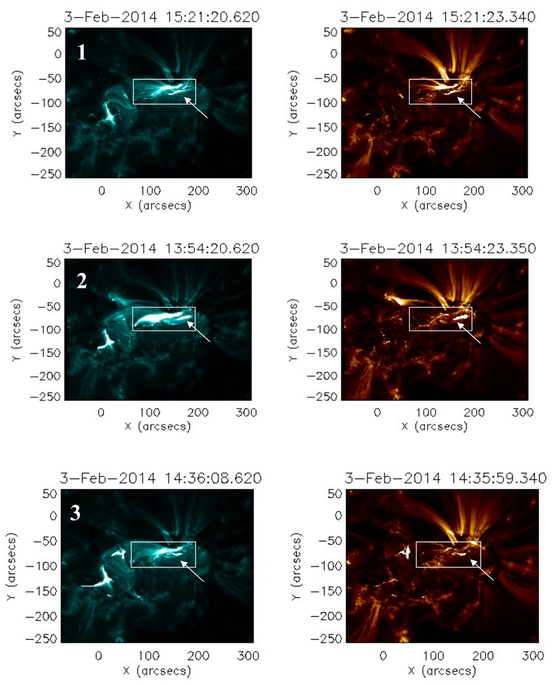
Another peak at around 15:21 UT (indicated as 3 in the AIA light curves below) is seen in the AIA filters but not in the GOES light curves.

SDO AIA Light Curves

SDO AIA light curves



AIA Images at the times of the three post flare peaks

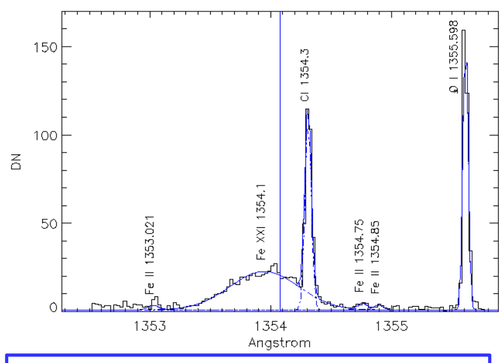


The light curves are calculated over the region enclosed by the white box in the figures on the right.
The first peak emission in the 1600 and 304 filters (13:22 UT) occurs before the flare peak in GOES (13:34 UT).
Also the IRIS Slit Jaw Images show an enhanced emission in the flare ribbons from around 13:22 UT.

The post-flare brightenings in the AIA filters seem to be associated with the appearance of coronal loops (indicated by a white arrow) which are visible in all the filters.

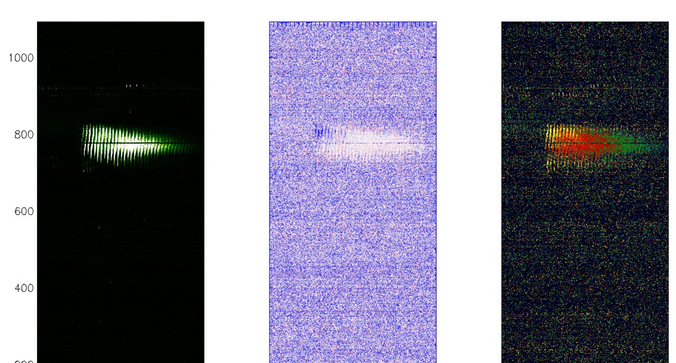
IRIS Fe XXI 1354.078A observation

IRIS Spectroraph FUVS detector, OI 1355 A spectral window



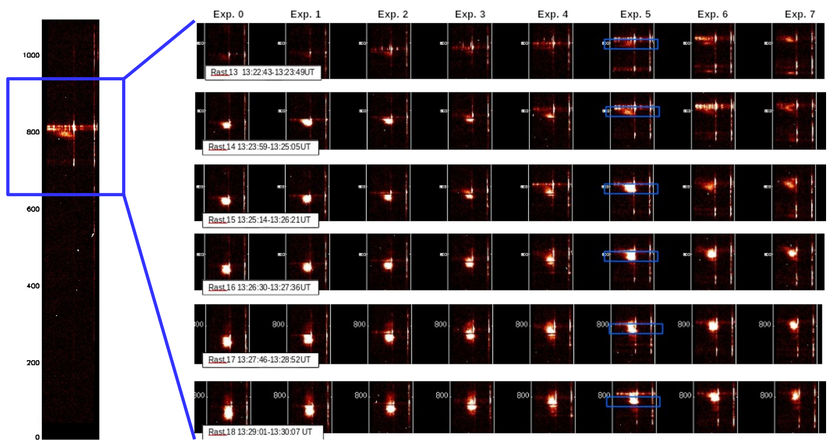
Fe XXI 1354.08 A is the highest temperature (10 MK) line observed by IRIS.
During solar flares, its intensity is comparable to that of the chromospheric lines in the same spectral range.

Intensity, velocity and FWHM maps over the whole observation (50 rasters, 400 temporal exposures in total)



The wavelength array has been corrected for orbital variation and then the absolute calibration has been performed using the OI 1335 A line as reference.

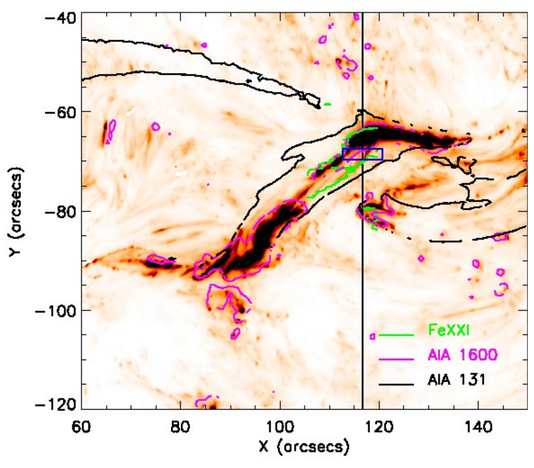
Examining positions where the Fe XXI is blueshifted: IRIS Spectrograph FUVS detector images



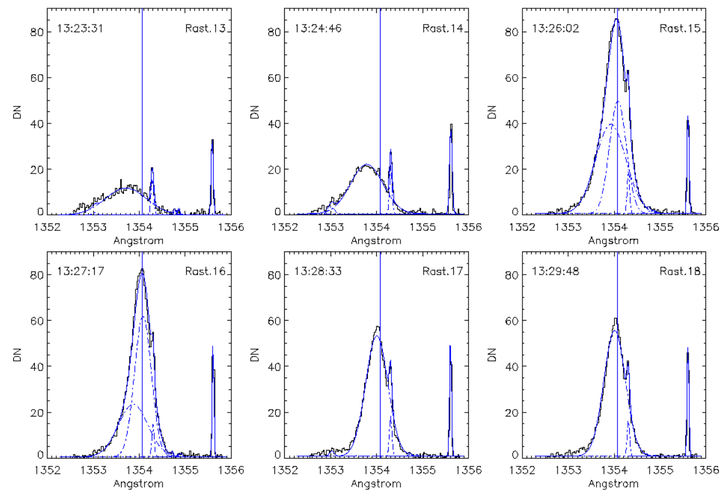
Blue asymmetries in the Fe XXI line profile are visible from raster 13 to raster no.18 . They are most intense in the raster exposure no. 5 (the location is indicated by the blue box on the detector images).

Fe XXI Gaussian line profile fitting

IRIS Slit Jaw (negative) Image overlaid with AIA contours, with the location of the slit exposure indicated for no. 5 ,13:24 UT

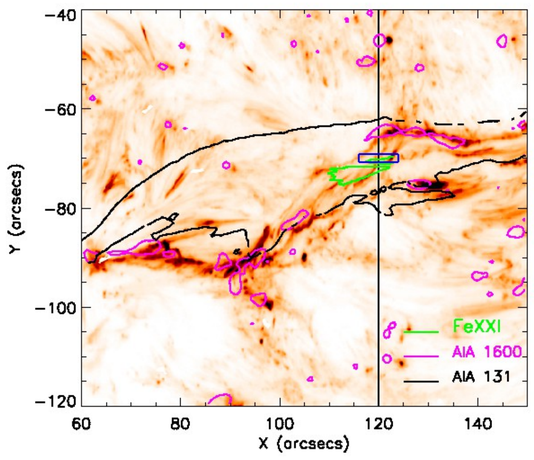


Fe XXI profiles, raster 13 to 18, exposure no.5 (13:23-13:29 UT), during the impulsive phase

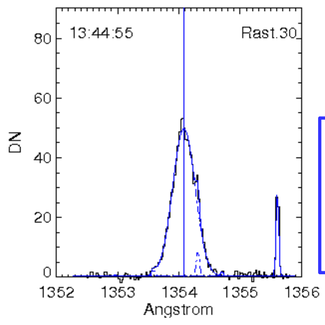


Fe XXI profiles during the impulsive phase (13:23-13:29 UT). The spectra were averaged spatially over the region indicated by the blue box on the slit jaw image on the left. The vertical blue line represents the Fe XXI rest wavelength position.

IRIS Slit Jaw (negative) Image overlaid with AIA contours, with the location of the slit exposure indicated for no. 5 ,13:45 UT

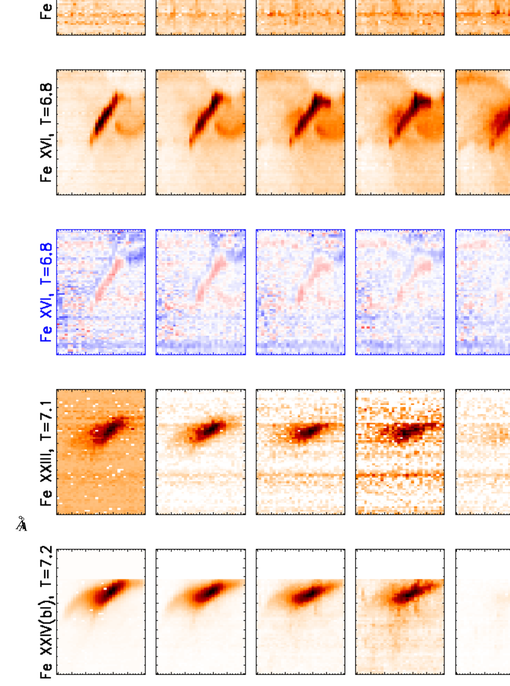


Fe XXI profile, raster 30 exposure no.5 (13:45 UT), during the gradual phase



The profile fits the expected rest position and a thermal width (FWHM = 0.429A) corresponding to a temperature of peak emission at 1.1 10^7 K for FeXXI.

Fe XXI blueshifts velocity and non-thermal width, raster 13 to 18, exposure no.5 (13:23-13:29 UT), during the impulsive phase



Summary of results

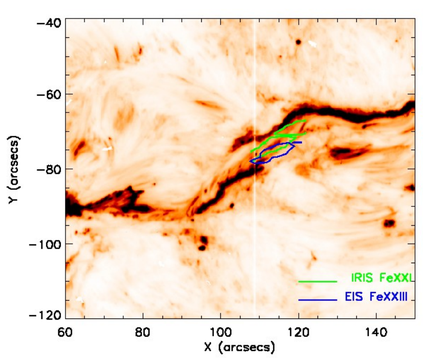
- In the early phase of the flare we see a **totally blueshifted FeXXI profile** from the northern ribbon.
- **The velocity of the blueshifted emission and the non thermal width decrease with time.**
- **Towards the peak phase, we see an increase in FeXXI emission at the rest wavelength,** which we interpret as coming from the flare loops as they fill. Indeed, this rest emission progressively moves towards the middle of the two ribbons.
- Later (13:36 UT) faint blueshifted Fe XXI emission is observed from the southern ribbon.

EIS observation: gradual phase

EIS intensity and velocity monochromatic (negative) images as a function of time

From top to bottom: Fe VIII 185.2 A, Fe XVI 262.98 A intensities; Fe XVI 262.98 A Doppler velocity of the centroid position: Fe XXIII 263.76 A, Fe XXIV (bl) 192.02 A intensities.

IRIS Slit Jaw (negative) Image with IRIS/Fe XXI and EIS/FeXXIII contourns, 13:37 UT



Summary of results

- **The hot temperature (10 MK) loops are seen in Fe XXIII and Fe XXIV until around 13:48 UT. Their emission is co-spatial with IRIS Fe XXI.** Their centroid positions are at rest at the time of the EIS observation, which starts at 13:35 UT.
- **The cooler Fe XVI emission (3 MK) presents a slight redshift (around 25 km/s)** of the centroid position along the loop. This indicates a downflow of the cooling flare plasma.
- During the first raster (13:35-13:39 UT), **some upflows (around 30 km/s)** still originate from the northern ribbon.

Acknowledgement. We thank the IRIS team (NASA) and the Hinode/EIS team (NASA, ISAS/JAXA, STFC). We acknowledge support from the IRIS team at Harvard-Smithsonian Centre for Astrophysics, STFC (UK) , the Isaac Newton Studentship and the Cambridge Trust.